Assessment of the EPA ICCR Emissions Database for Reciprocating Internal Combustion Engines

Prepared for:
Coordinating Committee of the
Industrial Combustion Coordinated Rulemaking (ICCR)

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I. Introduction

This paper presents the results of the Reciprocating Internal Combustion Engine (RICE) Work Group's assessment of the ICCR Emissions Database for RICE (RICE Emissions Database). The RICE Work Group has dedicated a significant effort to evaluating the available emissions data for RICE since February 1997. The assessment of the RICE Emissions Database was conducted in the context of determining the adequacy of the emissions data in the database to support the MACT rule development for stationary RICE. The Work Group developed this paper to document the work conducted over the past 18 months. The Work Group recommends that EPA consider this information in developing the MACT standard for stationary RICE.

The Emissions Database includes the available emissions data identified to date by EPA and the RICE Work Group to support the ICCR rule development for engines. The RICE Work Group and the ICCR Coordinating Committee have recommended to EPA that additional emissions data would better support the ICCR rule development. EPA has agreed to conduct the RICE Test Plan at the Colorado State University (CSU) Engines and Energy Conversion Laboratory. Members of the Work Group continue to support the RICE Test Plan by sharing the data collection and analysis burden. The recommendation for additional testing was based largely on the results of the Work Group’s review of emissions data included in the ICCR Emissions Database for RICE.

Section II of this paper provides a description of the characteristics of the emissions data currently included in the ICCR Emissions Database for RICE, including a breakdown of the data by subcategory and a summary of the available emissions data for control devices. Section III provides a summary of the results of the Work Group's review of the emissions data in the database. The final section of this paper presents the Work Group's conclusions and recommendations regarding the emissions data included in the database.

II. Characteristics of the HAPs Emissions Data Included in the RICE Emissions Database

The RICE Emissions Database (version 2.0) includes 92 test reports, with over 448 emissions tests for stationary RICE -- 171 emissions tests include HAP emissions data, 344 emissions tests include criteria pollutant data, and 67 tests include both HAP and criteria pollutant data. The tests incorporate the measurement of 45 HAPs. For each test report, EPA has calculated emission factors for HAPs in a consistent manner based on the emission concentration reported. When a single test included more than one run, the concentrations reported in each run are averaged. When a test includes HAPs that were not detected at levels above the method's detection limit (non-detects), EPA has calculated emission factors based on a percentage of the method's detection limit. EPA has flagged those values calculated based on a percentage of the detection limit with a less-than sign (<). If all runs conducted for an emissions test resulted in non-detects, EPA has flagged the data with a double less-than sign (<<). If concentrations were measured in at least one run, and other runs included non-detects, EPA has flagged the data with a single less-than sign (<). EPA included these data flags to identify those emission factors based on non-detects and to facilitate review of these data in the future. A description of the development of the emissions database, including assumptions used in the calculations is provided as **Appendix A**. EPA and the RICE Work Group have performed quality assurance reviews of a representative number of the emissions test reports and determined which reports should be considered adequate for general assessment of HAP emissions from stationary RICE. This review is discussed in **Section III** of this paper.

A summary of the sources of the emissions data in the ICCR Emissions Database is provided below. In addition, a summary of the emissions data included in the database for the RICE subcategories is presented, along with a summary of the emissions data for control devices.

A. Sources of Emissions Data

The RICE Emissions Database was compiled by EPA principally from the following sources:

- Source test reports (compliance tests) identified in EPA's Source Test Information Retrieval System (STIRS),
- Source test reports (compliance tests) submitted by Work Group members, and
- Emissions tests conducted by the Gas Research Institute (GRI).

No standard protocol was used to conduct the emissions tests included in the RICE Emissions Database. The HAPs reported, test methods used, detection limits, operating conditions tested, and reasons why testing was performed vary significantly from test to test. Most of the STIRS test reports with HAP emissions data come from California air pollution control districts and were conducted by source owners and operators to comply with California's AB2588 air toxic regulation. In those cases, test methods developed and approved by the California Air Resources Board (CARB) are generally used to quantify emissions. The target HAPs for the California tests vary since the target HAPs were negotiated with the local air pollution control district.

The database also includes source test reports collected by Work Group members. EPA and Mr. Don Price of the Ventura County Air Pollution Control District have requested copies of additional emissions test reports for stationary RICE from various districts in California. Although the Work Group has not reviewed the additional test reports, the Work Group agreed that the data from these test reports should be included in the RICE Emissions Database. Based on available information, it is anticipated that these test reports will be similar in quality to those compiled by EPA from the California districts.

The database also includes 112 emissions tests conducted by the Gas Research Institute (GRI) for natural gas-fired engines. These emissions tests were conducted by GRI in cooperation with GRI member companies.

B. Emissions Data by Subcategory

The RICE Work Group has identified the following subcategories for existing RICE:

- Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines
- Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines
- Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines
- Spark-Ignition, Digester Gas and Landfill Gas Engines
- Spark-Ignition, Propane, Liquid Petroleum Gas (LPG), and Process Gas Engines
- Spark-Ignition, Gasoline Engines
- Compression-Ignition, Liquid Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)

- Compression-Ignition, Dual Fuel Engines
- Emergency Power Units
- Small Engines (200 brake horsepower or less)

The RICE Emissions Database includes emissions data for all the subcategories identified by the RICE Work Group, except for Spark-Ignition, Gasoline Engines and Compression-Ignition, Dual Fuel Engines. Engines tested range in size from 54 horsepower (hp) to 5,500 hp. A summary of the number of emissions tests included in the database, by subcategory, is presented in **Table 1**. Most of the emissions data are for natural gas-fired engines and diesel engines, which, according to the ICCR Population Database, represent over 95 percent of stationary RICE.

For the fuels other than natural gas and diesel, there are a limited number of HAP emissions tests included in the RICE Emissions Database. For the Spark-Ignition, Digester Gas and Landfill Gas subcategory, 14 emissions tests are included in the database for digester gas, and one emissions test is included in the database for landfill gas. For the Spark-Ignition, Propane, LPG, and Process Gas subcategory, 1 HAP emissions test is included in the database for propane (on a small engine) and no HAP emissions tests are included for process gas or LPG. For Compression-Ignition, Liquid-Fuel Engines, all emissions tests included in the RICE Emissions Database are for diesel fuel, and no emissions tests are included for kerosene/naphtha, or heavier fuels, such as residual/crude oil. For the Emergency Power Units subcategory, three emissions tests indicate the engines are generators, but there is insufficient information to determine if they are for emergency use. Two of these tests indicate that multiple engines were included in the tests (common stack) and therefore, it is unclear which engine(s) are represented by the emissions test data.

Table 1. HAP Emissions Tests for Each RICE Subcategory

RICE Subcategory	Emissions Tests
Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines[1]	22
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines[1]	32
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines[1]	56
Spark-Ignition, Digester Gas and Landfill Gas Engines	15
Spark-Ignition, Propane, LPG, and Process Gas Engines[2]	0
Spark-Ignition, Gasoline Engines	0
Compression-Ignition, Liquid-Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)	26
Compression-Ignition, Dual Fuel Engines	0
Emergency Power Units	Unknown[3]
Small Engines (200 brake horsepower or less)	19

[1] One emissions test for a natural gas-fired engine could not be subcategorized.

[2] One emissions test report, with seven emissions tests, was included in the Database for an engine firing propane. Since the engine is rated at 39 hp, these tests are included in the small engine subcategory.

[3] Three emissions tests were conducted on generators, but the emissions tests do not indicate whether the engines are used for emergency power.

C. HAP Emissions Data for Engines with Criteria Pollutant Control Devices

Most HAP emissions tests included in the RICE Emissions Database were conducted on RICE without emissions controls. In some cases engines with NOx controls, including pre-combustion chambers (PCC), low emissions combustion (LEC), selective catalytic reduction (SCR), and non-selective catalytic reduction (NSCR), were tested. Also, 6 tests were conducted on engines using oxidation catalysts for carbon monoxide (CO) control. **Table 2** includes a summary of the emissions tests for criteria pollutant control devices, by subcategory.

Table 2. HAP Emissions Tests for Criteria Pollutant Control Devices

RICE Subcategory	Criteria Pollutant Control Devices Tested	
Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines	Non-Selective Catalytic Reduction	8
	Pre-Combustion Chamber	1
	Pre-Stratified Charge	1
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines	Pre-Combustion Chamber	13
	Pre-Stratified Charge	2
	Selective Catalytic Reduction	5
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines	Pre-Combustion Chamber	3
	Oxidation Catalyst for CO Reduction	6
Spark-Ignition, Digester Gas and Landfill Gas Engines	None	
Spark-Ignition, Propane, LPG, and Process Gas Engines	None	
Spark-Ignition, Gasoline Engines	None	
Compression-Ignition, Liquid-Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)	Selective Catalytic Reduction	1
Compression-Ignition, Dual Fuel Engines	None	
Emergency Power Units	None	
Small Engines (200 brake horsepower or less)	None	

III. Results of Work Group Assessment of the Emissions Database

In February 1997, the ICCR Coordinating Committee requested that Work Groups review available emissions to determine whether there was sufficient data available to support the ICCR rulemaking and to identify emissions data gaps that would need to be addressed to support the rulemaking. The RICE Work Group established the Emissions Subgroup to review the emissions data in the EPA ICCR Emissions Database for RICE. Members of the Subgroup reviewed the emissions test reports that were the source of the ICCR emissions data for RICE.

As a part of this review, the RICE Work Group conducted a detailed QA\QC review of the emissions test reports included in the database, largely emissions tests submitted by source owners and operators in California to respond to requirements from State or local air regulatory agencies. The Work Group used the information collection request (ICR) designed by the Work

Group for RICE as the format for the QA\QC review. A copy of the data form used by the Work Group to conduct the QA\QC review is provided in **Appendix B.**

The results of the Work Group's review of the emissions database may be summarized as follows:

1) Source tests from State and local air regulatory agencies provide "snapshots" of emissions from RICE in real-world applications. The source tests include insufficient information to fully evaluate the operating status of the engine when tested or to draw conclusions about the effects of operating conditions on HAPs. Where possible, EPA contacted the facilities and added information about the engineering parameters of the engines tested. In addition, the information about the engine family was added based on the engine manufacturer and model.
2) The RICE Emissions Database does not contain data to evaluate the effectiveness of catalytic controls, such as non-selective catalytic reduction (NSCR) or oxidation catalysts, throughout the full range of engine operating conditions.
3) Additional emissions data would better support the regulatory development of the RICE MACT standard.
4) Emissions estimates based solely on non-detects should not be used for regulatory purposes. [As noted above, EPA has flagged the emission factors in the ICCR Emissions Database that are based on non-detects.]
5) CARB 430 data from 3 emissions tests for natural gas-fired lean burn engines has evidence of interference. Other emissions tests with CARB 430 data had insufficient information for the Work Group to conclusively determine whether interference had occurred.

Additional discussion of the reviews conducted by the Work Group to draw these conclusions is provided below.

A. Emissions Data in Source Tests from State and Local Agencies

In March 1997, the Emissions Subgroup of the RICE Work Group reported on the results of the assessment of emissions data in source tests from state and local agencies. The Subgroup noted that the emission levels reported in the source tests were highly variable. For example, emissions of formaldehyde reported in the database for natural gas-fired engines cover six orders of magnitude, from 4.43E-07 pounds per million British Thermal Unit (lb/MMBTU) to 7.23E-01 lb/MMBTU. [The data for lean burn natural gas-fired engines are presented in **Figures 1** and **2**.] The Subgroup suggested that the variability could be attributed to two possible causes: 1) reported formaldehyde levels in some cases may be artificially low due to interference with DNPH-based test methods, and 2) emissions may be affected by the operating condition of the engine when tested.

When the Subgroup reviewed the test reports, the Subgroup noted that although the source tests were generally complete as it relates to documentation of the stack testing procedures and QA\QC for the test methods, the tests lacked information about the engine process. The RICE Work Group agreed that the HAP emissions tests obtained from state and local air regulatory agencies were conducted by source owners and operators in response to air regulatory requirements. Therefore, the goals for the testing were limited to the air regulatory requirements, rather than the goal of documenting emissions throughout the operating range or determining the effects of engine operating conditions on HAP emissions. Tests that provide detailed information about engine emissions throughout the full range of engine operating conditions are not required in the regulatory context, and therefore, tests with that level of detail are not available from state and local air regulatory agencies.

The test reports lacked key information about engineering and operating parameters that could affect HAP emissions. For example, the manufacturer and model of the engine were often lacking in test reports. Information about whether the engine was a 2-stroke or 4-stroke cycle was absent. The air-to-fuel ratio was often lacking, as was the horsepower and speed (rated and as tested). In addition, the engines apparently were tested in an "as-found" condition without full consideration of the reciprocating internal combustion process.

The Subgroup concluded that there was insufficient information in the test reports to account for the unexplained variability in the emissions data included in the ICCR Emissions Database for RICE. The Subgroup also concluded that, apparently, there are no existing data for testing a single engine over the entire envelope of operating conditions.

Based on the RICE Work Group's review, several key parameters were identified that would be necessary to fully evaluate the emissions data included in the RICE Emissions Database, including the following:

- Fuel used during emissions testing
- Engine manufacturer and model
- Engine subcategory
- Horsepower and speed (rated and as-tested)

Where possible, EPA contacted the tested facilities and obtained missing information. In general, the additional information obtained from the facilities included engine manufacturer and model and rated horsepower and speed. Information about the operating conditions of the engine during the emissions tests generally were not available. Information about engine subcategory was added to the database by using the engine manufacturer and model and information available from the engine manufacturers to determine which subcategory the engine should be placed in.

It is the conclusion of the RICE Work Group that, for those tests that met QA\QC review, the emissions data in source tests from state and local agencies only provided "snapshots" of the HAP emissions from the engines at the time of testing. The emissions tests evidently were not conducted over multiple operating conditions that might be seen by the engine in its application. Also, key information about the engine status was missing from the test reports, and could not be added. While this may have been sufficient for compliance purposes, it is not sufficient for determining HAP emissions throughout the operating range or for determining the effect of engine operating conditions on HAP emissions. Therefore, the RICE Work Group concluded that the data was inadequate to fully evaluate the range of emissions that would be anticipated from the unit throughout its operating range. In addition, the Work Group concluded that data included in the Emissions Database (version 2.0) should not be used to evaluate the effects of operating conditions on HAP emissions.

Emissions data throughout the operating range are necessary to fully evaluate HAP emissions from stationary RICE because engine operating parameters affect the physical and chemical mechanisms that result in the production of formaldehyde and other similar HAPs in ways that are indirect, complicated and often interrelated. For example, for large-bore natural gas-fired engines, increasing load typically increases the captured fuel air ratio, average cylinder temperature and exhaust temperatures, and peak pressure. It also affects mixing, level of turbulence, and flame propagation in unknown ways. This makes any evaluation of the effects of engine operation on formaldehyde both difficult and speculative given the present state of understanding.[1]

B. Emissions Data to Determine Efficiencies of Catalytic Controls

The RICE Work Group reviewed the emissions tests reports to determine if there was sufficient information to determine the effectiveness of controls that may reduce HAPs. Based on the Work Group's review of existing control devices, the group determined that existing catalytic controls for carbon monoxide (CO) reduction may also oxidize certain HAPs, such as formaldehyde. The Work Group identified non-selective catalytic reduction (NSCR) as a possible MACT control for natural gas-fired 4-stroke rich burn engines. Oxidation catalysts were identified as a possible MACT control for natural gas-fired lean-burn engines and for diesel engines. Catalytic controls were not identified for the Digester Gas/Landfill Gas subcategory because these fuels commonly contain siloxanes and other trace components, which foul catalysts.

The RICE Emissions Database includes eight emissions test for non-selective catalytic reduction (NSCR) on natural gas-fired 4-stroke rich burn engines. There are six emissions tests for oxidation catalysts for lean-burn engines.
The RICE Work Group concluded that there was insufficient data to evaluate the effectiveness of NSCR and oxidation catalysts over the full operating range. The data in the Emissions Database for NSCR include a limited number of pollutants and high detection limits (FTIR with a 0.5 ppm detection limit), so that non-detects were frequently reported. The data in the Emissions Database for oxidation catalysts lack sufficient emissions data before and after the control device to estimate representative control efficiency, and only a small portion of the pollutants were measured before and

[1] Factors Affecting the Measurement of CH_2O in Large-Bore Natural Gas Engines, C.E. Mitchell and D.B. Olsen, February 1998, ASME Paper 98-ICE-81, ICE-Vole. 30-1, 1998 Spring ASME-ICE Division Engine Technology Conference.

after controls.

C. Additional Emissions Data Would Better Support the RICE MACT

The RICE Work Group has concluded that additional emissions data would better support the ICCR rule development. This conclusion was reached as a result of the Work Group's review of emissions data available to the ICCR process in the EPA ICCR Emissions Database for RICE. The Work Group identified the following key emissions data gaps:

1. data to determine the effectiveness of after-treatment control devices to reduce formaldehyde and other HAPs;
2. data to evaluate the effectiveness of combustion modifications to reduce formaldehyde and other HAPs;
3. data to determine typical emissions for engines throughout the operating range.

The Work Group designed the RICE Test Plan (forwarded to EPA by the Coordinating Committee) to provide data to assess the effectiveness of after-treatment control devices to reduce formaldehyde and other HAPs. The Work Group designed the test plan to address this data gap for the following reasons:

- Emissions data to demonstrate the effectiveness of possible MACT control devices for existing RICE is a data gap in the ICCR Emissions Database for RICE.
- Understanding of the effects of combustion modifications on HAPs is in its infancy, and would require a very extensive research program to identify potential control techniques, along with confirming testing.
- EPA has endorsed the use of ICCR emissions testing dollars to achieve this goal.

The RICE Test Plan also will provide data to partially fill the data gap on baseline emissions from engines, since pre-controlled emissions throughout a 16-point test matrix of operating conditions will be recorded during the testing program.

D. Non-Detect Values

In accordance with the guidance provided by the Testing and Monitoring Work Group (TMDETECT.pdf), the RICE Work Group reviewed non-detect values at the Work Group meeting on November 20, 1997. As a result of the meeting, the Work Group resolved to accept the ICCR Testing and Monitoring Work Group's recommendations, including the following:

- No decisions leading to requirements for control devices or emissions limits on combustion processes should be made that are based on emission levels derived from default HAP concentrations calculated from method detection levels.
- The process recommended by the ICCR Testing and Monitoring Work Group should be used to evaluate non-detect data, including use of 1/2 of detection limits for existing data.
- Where non-detects are present, they should be carefully documented to ensure that MACT decisions are not made based on non-detect values.

As indicated above, EPA has flagged emission factors in the ICCR Emissions Database that were calculated based on non-detects. **Table 3** presents the pollutants, by subcategory, for which all emission estimates in the database are based on non-detects only. **Table 4** presents those pollutants, by subcategory, for which some emission estimates are based on non-detects and some emission estimates are based on measured concentrations.

The RICE Work Group concurs with the Testing and Monitoring Work Group's recommendations regarding non-detects. The Work Group recommends that this guidance be used by EPA in evaluating emissions data in the RICE Emissions Database that includes non-detect values. Also, the Work Group recommends that this guidance be used to evaluate any non-detects that are reported as a part of the emissions testing under the RICE Test Plan.

Table 3. Pollutants, by Subcategory, for Which All Emissions Estimates in the Database are Based on Non-Detects Only

RICE Subcategory	Pollutant	Number of Emission Estimates Based on Non-Detects Only
Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines	1,1,2-Tetrachloroethane	6
	1,1-Dichloroethane	6
	1,2-Dichloroethane	6
	1,2-Dichloropropane	6
	1,3-Dichloropropene	6
	Carbon Tetrachloride	6
	Chlorobenzene	6
	Chloroform	6
	Ethylene Dibromide	6
	Styrene	6
	Vinyl Chloride	6
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines	1,1,2,2-Tetrachloroethylene	9
	1,1,2-Tetrachloroethane	9
	1,1-Dichloroethane	9
	1,2-Dichloroethane	9
	1,2-Dichloropropane	9
	1,3-Dichloropropene	9
	Carbon Tetrachloride	9
	Chlorobenzene	9
	Chloroform	9
	Ethylene Dibromide	9
	Vinyl Chloride	9

RICE Subcategory	Pollutant	Number of Emission Estimates Based on Non-Detects Only
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines	1,1,2,2-Tetrachloroethylene	6
	1,1,2-Tetrachloroethane	6
	1,1-Dichloroethane	6
	1,2-Dichloroethane	6
	1,2-Dichloropropane	6
	1,3-Dichloropropene	6
	Carbon Tetrachloride	6
	Chlorobenzene	6
	Chloroform	6
	Ethylene Dibromide	6
	Vinyl Chloride	6
Spark-Ignition, Digester Gas and Landfill Gas Engines (all non-detects are for Digester Gas only)	1,1,1-Trichloroethane	14
	1,3-Butadiene	14
	1,4-Dioxane	14
	Carbon Tetrachloride	8
	Chloroform	14
	Ethylene Dibromide	11
	Ethylene Dichloride	14
	Tetrachloroethylene	14
	Trichloroethylene	14
	Vinyl Chloride	14
	Vinylidene Chloride	14
Spark-Ignition, Propane, LPG, and Process Gas Engines	None	
Spark-Ignition, Gasoline Engines	None	
Compression-Ignition, Liquid-Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)	Beryllium	3
	Selenium	3
Compression-Ignition, Dual Fuel Engines	None	
Emergency Power Units	Unknown	

RICE Subcategory	Pollutant	Number of Emission Estimates Based on Non-Detects Only
Small Engines (200 brake horsepower or less)	1,1,1-Trichloroethane (Digester Gas)	3
	1,3-Butadiene (Digester Gas)	3
	1,4-Dioxane (Digester Gas)	3
	Carbon Tetrachloride (Digester Gas)	3
	Chloroform (Digester Gas)	3
	Ethylene Dibromide (Digester Gas)	3
	Ethylene Dichloride (Digester Gas)	3
	Naphthalene (Propane & Natural Gas)	9
	Tetrachloroethylene (Digester Gas)	3
	Trichloroethylene (Digester Gas)	3
	Vinylidene Chloride (Digester Gas)	3

Source: ICCR Emissions Database Version 2.0, LB/MMBtu Report

Table 4. Pollutants, by Subcategory, for Which Some Non-Detects and Some Measured Concentrations Were Reported

RICE Subcategory	Pollutant	Number of Emission Estimates Based on Non-Detects Only	Number of Emission Estimates Based on Measured Concentrations
Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines	1,1,2,2-Tetrachloroethylene	5	1
	Acrolein	6	7
	Acetaldehyde	6	7
	Ethylbenzene	6	5
	Formaldehyde	3	15
	Methylene Chloride	2	4
	Naphthalene	5	3
	Toluene	3	13
	Xylene(s)	6	10
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines	Acrolein	11	8
	Acetaldehyde	13	3
	Ethylbenzene	4	10
	Formaldehyde	1	22
	Methylene Chloride	4	5
	Styrene	9	1
	Xylene(s)	1	13
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines	Acrolein	31	8
	Acetaldehyde	33	16
	Ethylbenzene	7	9
	Methanol	9	33
	Naphthalene	1	1
	Styrene	6	3
	Xylene(s)	7	11

RICE Subcategory	Pollutant	Number of Emission Estimates Based on Non-Detects Only	Number of Emission Estimates Based on Measured Concentrations
Spark-Ignition, Digester Gas and Landfill Gas Engines	Acrolein Benzene Dichlorobenzene Methylene Chloride Styrene Xylene	1 1 8 2 7 1	13 13 6 12 7 13
Spark-Ignition, Propane, LPG, and Process Gas Engines	None		
Spark-Ignition, Gasoline Engines	None		
Compression-Ignition, Liquid-Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)	1-3, Butadiene Formaldehyde n-Hexane	1 8 1	1 17 1
Compression-Ignition, Dual Fuel Engines	None		
Emergency Power Units	Unknown		
Small Engines (200 brake horsepower or less)	Acrolein (Digester Gas) Vinyl Chloride (Digester Gas)	1 2	5 1

Source: ICCR Emissions Database Version 2.0, LB/MMBtu Report

E. CARB 430 Data for Natural Gas-Fired Lean Burn Engines

In accordance with the guidance provided by the Testing and Monitoring Work Group (FORMALD1.WP6), the RICE Work Group reviewed the issue of formaldehyde data for natural gas-fired lean-burn engines collected using methods, such as CARB 430, that rely on a DNPH solution to quantify formaldehyde concentrations. The Gas Research Institute (GRI) first advised EPA that there could be NO2 depletion of the DNPH solution when DNPH-based methods are used on natural gas-fired lean-burn engines. In the case of high NO2 levels, the DNPH may be depleted so that formaldehyde levels for lean-burn engines are underreported. GRI had noted the problem when conducting side-by-side testing with its EPA-approved method, using FTIR, and the CARB 430 method, using a DNPH solution. CARB 430 data is included in the RICE Emissions Database for both 4-stroke lean burn and 2-stroke lean burn natural gas-fired engines.

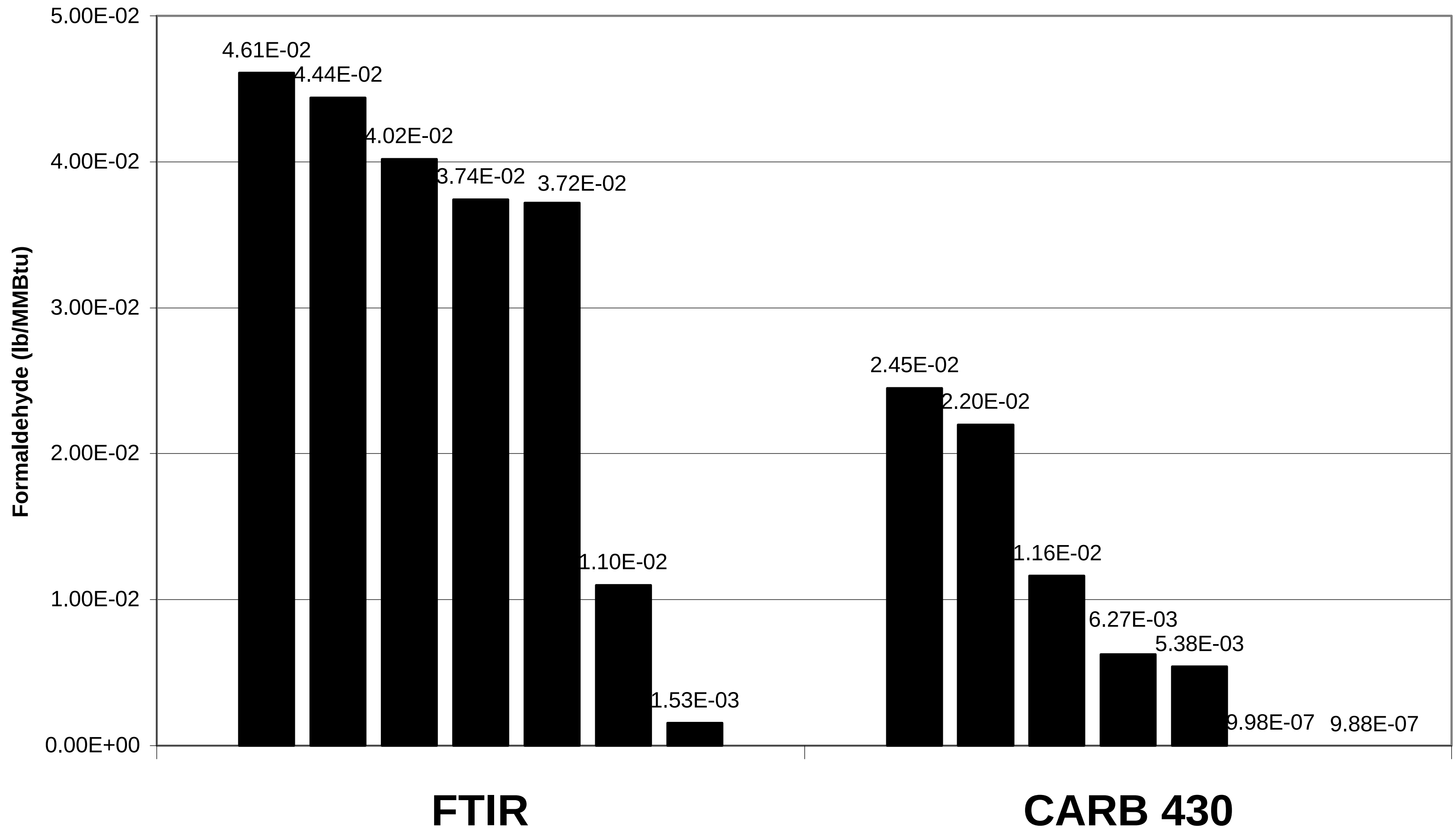
The Work Group initiated the review of CARB 430 data in the Work Group meeting on November 20, 1997. As a result of the meeting, the Work Group requested that EPA compare the CARB 430 data for natural gas-fired lean burn engines to data collected for lean burn engines using FTIR. The criteria for review were based on the recommendations of the Testing and Monitoring Work Group and recommendations from Mr. Jim McCarthy of the Gas Research Institute (GRI).

The results of EPA's review were reported to the Work Group in a memorandum of March 5, 1998. Based on EPA's review, a total of 3 emissions tests, of 16 tests reviewed, included adequate information to determine that there was a problem with the CARB 430 data. These emissions tests have been tagged with an "x" in the database (for pollutants measured with CARB 430) to indicate that the emissions tests do not include acceptable HAP emissions data for those pollutants measured with CARB 430.

EPA reported that the 13 other emissions tests conducted with CARB 430 did not contain sufficient information to determine definitively that there was interference with the method. EPA also conducted a preliminary statistical analysis of the CARB 430 data. Based on that preliminary analysis, EPA concluded in the March 5 memorandum that the remaining data from CARB 430 and FTIR for 4-stroke lean burn and 2-stroke lean burn engines are equivalent. Most of the RICE Work Group members did not concur with EPA's conclusion that the data are equivalent. These Work Group members believe that questions remain about the CARB 430 data for natural gas-fired lean burn engines and that further analysis of the data is warranted.

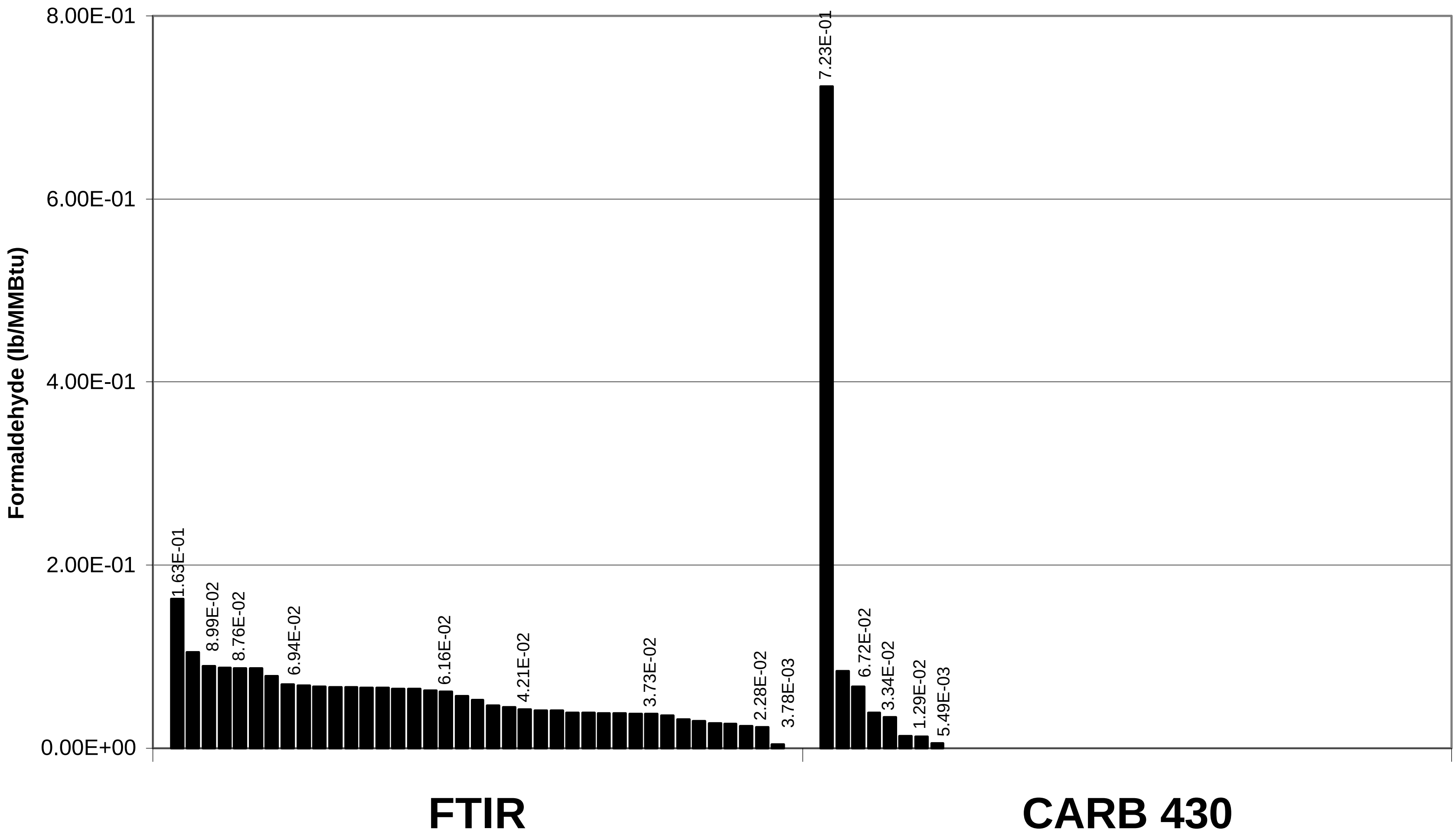
The formaldehyde emissions data included in the RICE Emissions Database for natural gas-fired 4-stroke lean burn engines is presented in **Figure 1**. The formaldehyde emissions data included in the database for natural gas-fired 2-stroke lean burn engines is presented in **Figure 2**.

Figure 1. Formaldehyde Values for Natural Gas-Fired 4-Stroke Lean Burn Engines



(data presented are from independent testing, not simultaneous testing)

Figure 2. Formaldehyde Data for Natural Gas-fired 2-Stroke Lean Burn Engines



(data presented are from independent testing, not simultaneous testing)

IV. Conclusions and Recommendations

RICE Work Group concludes that additional emissions data would better support the ICCR rule development for the following reasons:

- Variability of the emissions data in the RICE Emissions Database cannot be explained with available information.
- Information about the engine process during emissions testing from state and local agencies is insufficient to understand how emissions vary over full operating range.
- Emissions data before and after catalytic control devices that may reduce HAP emissions, including NSCR and oxidation catalysts, is inadequate to evaluate the effectiveness of those devices on reducing HAP emissions throughout the full operating range.
- There are questions remaining about existing emissions data for natural gas-fired lean-burn engines from tests using CARB 430 and other DNPH-based methods (where NO2 may have depleted the DNPH solution). The RICE Work Group has recommended that FTIR be used to measure formaldehyde emissions in future EPA emissions testing for natural gas lean burn engines.

The RICE Work Group urges EPA to conduct the RICE Test Plan at Colorado State University (CSU) to address these data issues. In addition, the Work Group recommends that EPA rely on data from the RICE Test Plan and similar data of that caliber to assess the efficiency of HAP emissions control technology, such as NSCR and oxidation catalysts, throughout the full operating range. Although the RICE Emissions Database does not adequately address the issues listed above, there still may be appropriate uses for the data as a part of the regulatory development for RICE. The data does provide "snapshot" emissions data for a variety of stationary RICE. This data is relevant to EPA's analysis of the achievability of any emission limitations under consideration for the RICE MACT.

Finally, the RICE Work Group underscores the need to implement the Testing and Monitoring Work Group guidance on non-detects for all emissions data that may be used to support the MACT rule development.

APPENDIX A

HAP Emission Data Calculations for RICE Emissions Database

EPA developed a Microsoft Access database for HAP emissions data for reciprocating internal combustion engines. The RICE Emissions Database includes the measured emissions concentrations and all other parameters necessary to calculate emission rates and factors. The database also includes physical and operational parameters which may affect HAP emissions. A total of 1386 records from 30 test reports are included in the database. Each record contains information from up to three test runs for an identified HAP.

Unreported emissions are presented as "NR." Unreported emissions are the result of missing parameters such as pollutant concentration, fuel type, engine type and size, stack exhaust flowrate, or fuel consumption levels. Typically, each test consisted of three test runs. For the tests where at least one run (but not all runs) revealed an undetected concentration, a "<" sign precedes the calculated emission rates and factors. In cases where the pollutant was not detected in all test runs, the emission concentrations are presented as "ND", and a "<<" sign precedes the calculated emission rates and factors. All emission rates and factors corresponding to undetected concentrations are calculated based on the reported pollutant detection limit.

The emission factors and rates were determined using EPA recommended calculations. Emissions factors in lb/MMBtu were determined according to EPA Method 19 referenced in 40 CFR part 60, Appendix A. These factors are based on the measured pollutant concentration, fuel factor, and stack oxygen levels. Emission rates in lb/hr were determined using standard engineering calculations and are based on the measured pollutant concentration, exhaust stack flow rate, and the exhaust temperature. Emission factors in lb/HP-hr were based on the calculated emission rates (lb/hr), engine rating (HP), and load conditions. In cases where the fuel factor was not provided, EPA used the fuel factors provided in 40 CFR 60. It should be noted that the 40 CFR 60 fuel factors are within 3 percent of the average reported fuel factors for natural gas, and within 2 percent of the average reported fuel factors for diesel fuel.

Emissions factors were calculated according to Equations 1 through 5 below. For gaseous HAPs, Equations 1 and 2 were used to calculate emission rates in lb/hr and emission factors in lb/MMBtu, respectively. For particulate HAPs, Equations 3 and 4 were used to calculate emission rates in lb/hr and emission factors in lb/MMBtu, respectively. Equation 5 was used to calculate emission factors in lb/HP-hr for both gaseous and particulate HAPs. Load conditions are incorporated into Equation 5 to account for engine output power.

Equation 1: Emission Rate in (lb/hr) for gaseous HAPs:

$$ER\left(\frac{lb}{hr}\right) = \frac{1.369x10^{-9}\left(\frac{lb\text{-}mol^{o}R}{ft^{3}}\right) x\, 60\left(\frac{\min}{hr}\right) x\, Q_{stk}\left(\frac{dscf}{\min}\right) x\, C\,(ppb)\, x\, M\left(\frac{lb}{lb\text{-}mol}\right)}{(T_{std} + 460)^{o}R}$$

where: ER = Emission rate (lb/hr)
Q_{stk} = Stack gas flow rate (dscf/min)
C = Measured concentration (ppb)
M = HAP molecular weight (lb/lb-mol)
T_{stk} = Stack temperature (^{o}F)

Equation 2: Emission Factor in (lb/MMBtu) for gaseous HAPs:

$$EF_{F}\left(\frac{lb}{MMBtu}\right) = \frac{1.369x10^{-9}\left(\frac{lb\text{-}mol^{o}R}{ft^{3}}\right) x\, F_{F}\left(\frac{dscf}{MMBtu}\right) x\, C\,(ppb)\, x\, M\left(\frac{lb}{lb\text{-}mol}\right) x\, \frac{20.9}{20.9 - \%\,O_2}}{(T_{std} + 460)^{o}R}$$

where: EF_F = Emission factor (lb/MMBtu)
F_F = Fuel factor (dscf/MMBtu)
$\%O_2$ = Percent oxygen in the stack

$$ER\left(\frac{lb}{hr}\right) = 3.70x10^{-9}\, C\left(\frac{mg}{dscm}\right) X\; Q_{stk}\left(\frac{dscf}{\min}\right)$$

Equation 3: Emission Rate in (lb/hr) for particulate HAPs:

where: C = Measured concentration (µg/dscm)

Equation 4: Emission Factor in (lb/MMBtu) for particulate HAPs:

$$EF_F\left(\frac{lb}{MMBtu}\right) = 6.23x10^{-11}\ X\ C\left(\frac{mg}{dscm}\right)\ X\ F_F\left(\frac{dscf}{MMBtu}\right)\ X\ \frac{20.9}{20.9 - \%O_2}$$

where: C = Measured concentration (μg/dscm)

Equation 5: Emission Factor in (lb/HP-hr) for both gaseous and particulate HAPs:

$$EF_P\,(lb/HP\text{ - }hr) = \frac{ER\,(lb/hr)}{P\,(HP)\;x\;(\frac{Load}{100})}$$

where: EF_p = Emission factor based on power output (lb/HP-hr)

P = Power output (HP)

Load = Load conditions of the tested engine**.**

APPENDIX B

INDUSTRIAL COMBUSTION COORDINATED RULEMAKING

INFORMATION COLLECTION REQUEST

Stationary Reciprocating Internal Combustion (IC) Engines

This version of the Reciprocating IC Engine Questionnaire was prepared 1/6/97

Part I: General Facility Information

1. **Facility identification number from NEDS, if available:______________________________**
   If the facility ID from NEDS is not available, provide a facility ID for use on this form:____________
2. **Name of legal owner of facility:____**
3. **Name of legal operator of facility, if different from legal owner:__________________________**
4. **Address of legal owner or operator:____**
5. **Size of company:**
   a. **approximate number of employees of the business enterprise that owns this facility, including where applicable, the parent company and all subsidiaries, branches, and unrelated establishments owned by the parent company (answer may be given using the following ranges: 0-100; 101-250; 251-500; 501-750; 751-1,000; 1,001-1,500; or >1,500):**
   b. **Number of facility employees:____**
6. **Name of facility:____**
7. **Type of facility:**
   a. **Description of type of facility:____**
   b. **Standard Industrial Classification (SIC) Code:_______________________________**
8. **Size of facility:**
   a. **Total number of stationary reciprocating IC engines at the facility (50 bhp or greater):______**
   b. **Total stationary horsepower (reciprocating IC engines 50 bhp or greater only):_________bhp**
9. **Location of facility:**
   a. **Name of County (or Parish) where facility is located:___________________________**
   b. **Complete street address of facility (physical location):__________________________**
   c. **Complete mailing address of facility (if different from street address):__________________**
10. **Name and title of contact(s) able to answer technical questions about the completed survey:_________**
11. **Contact telephone number: (____)_____________Fax: (____)__________e-mail:___________________**

PART II: Stationary Reciprocating Internal Combustion Engine Information

Please indicate the total number of stationary reciprocating internal combustion engines at the facility for each of the size classifications (per unit) included in the table below:

Rated Horsepower of Engine	Total Number of Stationary Engines at Facility	Number of Engines Listed in Previous Column that are Used for Emergency Standby Only
50-150		
151-300		
301-500		
501-750		
751-1000		
1001-1500		
1501-2000		
>2000		
Total Number of Engines		

For each engine included in the above table, please complete the Part III -- Engineering Information and Part IV -- Typical Operating Information forms, unless some units are identical. Identical units may be reported on the same Part III and Part IV forms. If identical units are reported on the Part III and Part IV forms, provide engine identification numbers for all units included on the same form. For the purposes of this survey, units may be considered identical only if all the following criteria are met:

a. All units have the same manufacturer and model number.
b. All engineering data for the units are the same.
c. All operating data for the units are the same.
d. The primary use of all the units is the same.

Photocopy this section in order to complete one Part III -- Engineering Information form for each stationary reciprocating internal combustion engine listed in the table in Part II. Identical units may be reported on the same form.

Part III: Engineering Information

1. Identification number(s) assigned by the facility for reciprocating IC engines reported on this form, e.g., Engine 001:____

2. Manufacturer Information:

- **a. Engine Manufacturer:____________________________________**
- **b. Engine Manufacturer's Model:______________________________**

3. Year Installed:________Has the combustion related hardware been changed since manufacture? ❑ yes ❑ no If so, when was the hardware changed:_____ Attach a brief description of what was done.

4. Engine Descriptors:

- **a. Ignition: ❑ Spark Ignition (SI) ❑ Compression Ignition (CI), i.e., Diesel**
  If SI, is the engine: ❑ Rich Burn ❑ Lean Burn
- **b. Stroke: ❑ 2-stroke cycle ❑ 4-stroke cycle**
- **c. Primary fuel: ❑ Liquid ❑ Gaseous ❑ Dual Fuel (pilot injection -- CI only)**

5. Please provide the following information which typically is available from the engine nameplate (note that certain of these values may be different from the operating values):

- **a. Bore:____________________________inches or mm (circle one)**
- **b. Stroke:___________________________ inches or mm (circle one)**
- **c. Displacement:_____________________cubic inches or liters (circle one)**
- **d. Rated Speed:______________________ rpm**
- **e. Rated Power:_____________________bhp or kW (circle one)**
- **f. Compression Ratio:________________: 1**
- **g. Spark timing (SI):_________________° BTDC or injection timing (CI):____________° BTDC**
- **h. Manufacturer's Serial Number(s):__________________________________**

6. Engine Configuration:

- **a. Cylinders: ❑ In-line ❑ Vee number of power cylinders:______________**
- **b. Engine aspiration (breathing):**
  - **i. If 2-stroke cycle: ❑ Blower Scavenged**
    ❑ Piston Scavenged
    ❑ Pump Scavenged
    Is it also: ❑ Turbocharged ❑ Turbocharged with aftercooling/intercooling ❑ Neither
  - **ii. If 4-stroke cycle: ❑ Naturally Aspirated**
    ❑ Turbocharged/Supercharged
    ❑ Turbocharged/Supercharged with aftercooling/intercooling
- **c. If equipped with aftercooling/intercooling, what is the design cooling water temperature?**
  ❑ 85° F (29.5° C) ❑ 130° F (54.5° C) ❑ Other -- specify ____________° F or ° C (circle one)

7. Primary engine use (please check one only):

- **❑ Electric power generation (e.g., prime power or peak shaving)**
- **❑ Co-generation (electricity plus heat)**
- **❑ Steam or heat generation only**
- **❑ Mechanical power (e.g., pump, blower, compressor, etc.)**
- **❑ Transport of a liquid or gas (e.g., pipeline transmission)**
- **❑ Waste destruction (e.g., combustion of landfill or process byproduct gas)**
- **❑ Emergency only (electrical or mechanical -- circle one)**
- **❑ Other -- Please describe:____**

Facility ID number:_______________ Company ID number(s) for reciprocating IC engine(s):________________

Photocopy this section in order to complete one Part IV -- Typical Operating Information form for each stationary reciprocating internal combustion engine listed in the table in Part II. Identical units may be reported on the same form.

Part IV: Typical Operating Information

Provide typical operating information on this form for each stationary reciprocating IC engine included in the Table in Part II. Please note that these values may be different from the rated or design data provided on the Part III -- Engineering Information form.

1. Hours of Operation (hr/yr): Typical:______________ Maximum:________________

2. Frequency of startups/shutdowns (no./yr): Typical:______________ Maximum:_______________
Hours during startups/shutdowns: Typical:________________ Maximum:_______________

3. Degree of automation: (check all that apply)
❑ manual ❑ local automatic ❑ remote automatic

4. Engine operating parameters (please note that certain of these values may be different from the rated values reported on the manufacturer's nameplate):

- a. Operating Speed:_________________rpm
- b. Operating Power:_________________ bhp or kW (circle one)
- c. Spark timing (SI):________________° BTDC or injection timing (CI):___________° BTDC
- d. Air to Fuel Ratio:_________________ by mass or by volume (circle one)
- e. BMEP__________________________psi or bar (circle one)
- f. Peak Firing Pressure:______________ psi or bar (circle one)
- g. Average Heat Input:______________ MMBtu/hr LHV or HHV (circle one) at________ bhp
- h. Maximum Heat Input:_____________ MMBtu/hr LHV or HHV (circle one) at ________ bhp
- i. Steam generation:_________________ MMBtu/hr (co-generation units only)

6. Stack parameters: before or after control device (circle one):_________________________________

- a. Exhaust Gas Flow Rate:____________ dscfm at _______________________________ bhp
- b. Exhaust Temperature:_____________ ° F at _________________________________ bhp
- c. Oxygen Concentration:_____________% by vol. at ____________________________ bhp

7. Are emissions control device operated for this unit? ❑ yes ❑ no If so, please enter the control device identification number(s) assigned by the facility____

8. Fuel used during normal operations (attach typical fuel analyses if available):

Fuel Use	Fuel Code	LHV of HHV Btu/SCF - Btu/gal (circle one)	% NMHC mass or vol. (circle one)	Pretreatment	Analysis Provided
Operating Fuel (1)	___________	_____________	________	❑ yes* ______	❑ yes
Operating Fuel (2)	___________	_____________	________	❑ yes* ______	❑ yes
Operating Fuel (3)	___________	_____________	________	❑ yes* ______	❑ yes
Startup Fuel	___________	_____________	________	❑ yes* ______	❑ yes
Standby Fuel	___________	_____________	________	❑ yes* ______	❑ yes

Fuel Codes: NG = Natural Gas LG = Landfill Gas GL = Gasoline RG = Refinery Gas
DF = Diesel Fuel BF = Process Byproduct DG = Digester Gas
CO = Crude Oil MX = Mixture:____
OT = Other:_

*** Please provide the pretreatment code from the list below. If a pretreatment code is not listed for the device or method of pretreatment, please enter OT for "Other" and attach a brief description.**

Pretreatment Codes: (Work Group needs to provide these)

Facility ID number:_________________ Company ID number(s) for reciprocating IC engine(s):____________

Photocopy this section in order to complete one Part V form for each emissions control device in service for the stationary reciprocating internal combustion engines listed in the table in Part II. Identical units may be reported on the same form.

Part V: Emissions Control Device Information

1. **Control device identification number assigned by the facility, e.g., CD 001:______________________**

2. **Does this control device control emissions from more than one IC engine? ❑ yes ❑ no**
   Identification number(s) for the reciprocating IC engine(s) served by this control device:___________
   ____
   ____

3. **Type of Emissions Control (check all that apply):**

   ___ Air to Fuel Ratio ___ Catalytic Reduction ___ Retrofit Low Emission Combustion
   ___ Catalytic Oxidation ___ Ignition Timing ___ Pre-stratified charge
   ___ Miscellaneous Control Devices, describe:____

4. **Manufacturer Information:**
   a. **Emissions Control Device Manufacturer:____**
   b. **Model:____**

5. **Year Installed:__________ Has permanent hardware been changed since manufacture? ❑ yes ❑ no**
   If so, when was the hardware changed:____________ Attach a brief description of what was done.

6. **Control Efficiency:**

Pollutant Controlled	Pre-Control Conc.* (ppm)	Post-Control Conc.* (ppm)	@15% O2	Other

* If the control device is low-emission combustion and the unit was purchased with the low emission combustion equipment, please provide only the post-control concentration.

7. **Waste Streams Generated Due to Control Device Operation:**

Waste Stream	Amount Per Year	Amount Disposed	Recycling Method
liquid wastewater			
liquid:__________			
solid:__________			
solid:__________			

8. **Control Costs:**
   a. **Capital costs for emissions control device:_____________________**
   b. **Annual costs for emissions control device:_____________________**
   c. **Do you have detailed cost information? ❑ yes ❑ no If so, would you be willing to provide that cost information at a later time? ❑ yes ❑ no**

Photocopy this section in order to complete one Part VI form for each reciprocating internal combustion engine for which emissions data is available.

Part VI: Emissions Information: Criteria Pollutants

NOTE: No New Testing is Required or Requested.

Report all limits included in current air permits in the **Permitted Emissions Limit** column in the table below. Report all **actual measured data** from air emissions tests in the **Measured Emissions** column in the table below. If no testing has been conducted for a pollutant listed in the table below, please draw a line through the pollutant name and mark an **"X"** in the **Measured Emissions** column. Do not report emissions based on emission factors provided by EPA, state or local agencies, or industry associations. If available, please submit a copy of the test report from which the data were obtained.

(If more than one device was vented through the stack on which measurements were made, please explain on a separate sheet.)

Pollutant	**Permitted Emissions Limit**[a]	**Measured Emissions**[b]	**Fuel Flow** (specify MCF or MMBtu/hr at LHV or HHV)	**Date(s) of Test(s)**	**O2 Level During Test (% dry)**	**Engine Load During Test (specify bhp or % rated bhp)**	**Test Method**[c]	**Number of Tests Included**[d]
CO	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
NOx	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
PM-10	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
SO2	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
VOC	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						

[a] Report all permitted emission limits that apply.

[b] Report any measured emission rates that are available. Do not report emissions information based on emission factors provided by EPA, or local agencies, or industry associations.

[c] Indicate the method 1) CEM; 2) Stack test, include test method, such as EPA Method 20, CARB Method 17; or 3) Other, include explanation.

[d] Provide the number of tests averaged to obtain the reported values.

[e] Pollutant concentrations reported as ppm should be reported as parts per million by volume on a dry basis, corrected to 15 percent oxygen content.

Facility ID number:____ Company ID number for reciprocating IC engine:__________________________

Fuel ID for fuel in use during testing:__________

Photocopy this section in order to complete one Part VI form for each reciprocating internal combustion engine for which emissions data is available.

Part VI: Emissions Information: Hazardous Air Pollutants

NOTE: No New Testing is Required or Requested.

Report all limits included in current air permits in the **Permitted Emissions Limit** column in the table below. Report all **actual measured data** from air emissions tests in the **Measured Emissions** column in the table below. If testing was conducted for a pollutant listed in the table, but the pollutant was not detected, report **"ND"** for "not detected" in the **Measured Emissions** column. If no testing has been conducted for a pollutant listed in the table below, please draw a line through the pollutant name and mark an **"X"** in the **Measured Emissions** column. Do not report emissions based on emission factors provided by EPA, state or local agencies, or industry associations. If available, please submit a copy of the test report from which the data were obtained.

(If more than one device was vented through the stack on which measurements were made, please explain on a separate sheet.)

Pollutant	Permitted Emissions Limit[a]	Measured Emissions[b]	Fuel Flow (specify MCF or MMBtu/hr at LHV or HHV)	Date(s) of Test(s)	O2 Level During Test (% dry)	Engine Load During Test (specify bhp or % rated bhp)	Test Method[c]	Number of Tests Included[d]
Acetaldehyde	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
Acrolein	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
Benzene	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
Dioxin	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
Formaldehyde	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						

[a] Report all permitted emission limits that apply.
[b] Report any measured emission rates that are available. Do not report emissions information based on emission factors provided by EPA, or local agencies, or industry associations.
[c] Indicate the method 1) CEM; 2) Stack test, include test method used, such as EPA Method 0011, Method CARB 430; or 3) Other, include explanation.
[d] Provide the number of tests averaged to obtain the reported values.
[e] Pollutant concentrations reported as ppm should be reported as parts per million by volume on a dry basis, corrected to 15 percent oxygen content.

Facility ID number:____ Company ID number for reciprocating IC engine:__________________________

Fuel ID for fuel in use during testing:__________

Photocopy this section in order to complete one Part VI form for each reciprocating internal combustion engine for which emissions data is available.

Part VI: Emissions Information: Hazardous Air Pollutants (continued)

NOTE: No New Testing is Required or Requested.

Report emissions for all other HAPs in the table below. A list of HAPs is provided as Attachment 1. Report all permit limits included in current air permits in the **Permitted Emissions Limit** column in the table below. Report all **actual measured data** from air emissions tests in the **Measured Emissions** column. If testing was conducted for a pollutant, but the pollutant was not detected, record the pollutant in the table below and report **ND** for "not detected" in the **Measured Emissions** column. Do not report emissions based on emission factors provided by EPA, state or local agencies, or industry associations. If available, please submit a copy of the test report from which the data were obtained.

(If more than one device was vented through the stack on which measurements were made, please explain on a separate sheet.)

Pollutant	Permitted Emissions Limit[a]	Measured Emissions[b]	Fuel Flow (specify MCF or MMBtu/hr at LHV or HHV)	Date(s) of Test(s)	O2 Level During Test (% dry)	Engine Load During Test (specify bhp or % rated bhp)	Test Method[c]	Number of Tests Included[d]
___________	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
___________	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
___________	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
___________	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						
___________	ppm[e] lb/hr g/bhp-hr	ppm[e] lb/hr g/bhp-hr						

[a] Report all permitted emission limits that apply.

[b] Report any measured emission rates that are available. Do not report emissions information based on emission factors provided by EPA, or local agencies, or industry associations.

[c] Indicate the method 1) CEM; 2) Stack test, include test method used, such as EPA Method 0011, Method CARB 430; or 3) Other, include explanation.

[d] Provide the number of tests averaged to obtain the reported values.

[e] Pollutant concentrations reported as ppm should be reported as parts per million by volume on a dry basis, corrected to 15 percent oxygen content.

Facility ID number:____ Company ID number for reciprocating IC engine:_____________________________

Fuel ID for fuel in use during testing:___________

APPENDIX C

Testing & Monitoring WG's September 1997 recommendations on interpreting and using emissions databases containing non-detection values are available on the ICCR portion of the EPA TTN:

http://www.epa.gov/ttn/iccr/dirss/tmdetect.pdf

APPENDIX D

July 8,1997

FORMALDEHYDE MEASUREMENTS BY THE DNPH METHODS: A REVIEW BY THE TESTING AND MONITORING WORKGROUP

A. Validity of data in the EPA Database

Studies carried out by Radian International for the Gas Research Institute (GRI) have raised questions regarding the validity of aldehyde emission measurements using the CARB 430 procedure[2]. The industry uses CARB 430, EPA 0011, and related 2,4-dinitrophenyl hydrazine (DNPH) colorimetric procedures to measure formaldehyde emissions from combustion sources. Much of the aldehyde emission data that are available for EPA rule formulation were collected using DNPH procedures. The intent of this memorandum is to provide further guidance to the ICCR Source Groups on deciding which data are valid, and what test methods might be used for future measurements.

The Radian report shows evidence that the problem is related to NO_2 (not to be confused with NO or NOx) in the exhaust gas. DNPH reacts with all aldehydes to form derivatives which are then separated and analyzed by liquid chromatography. Radian has also found that DNPH also reacts with NO_2 to form a derivative. This side reaction with NO_2 can lead to depletion of the DNPH or produce other substances that mask the color that is produced by the aldehyde-DNPH reaction. In general, we recommend that Source Groups should be cautious in their use of CARB 430 data in the EPA data base.

The GRI reported only comparative measurement between the Fourier Transform Infrared (FTIR) analyzer and CARB 430 for natural gas fired internal combustion engines and found discrepancies between data from the two methods only with lean or clean burn engines. The GRI stated that they have "...no evidence of problems with their CARB 430 applications to natural gas-fired boilers, heaters, turbines or rich burn engines." Their data also showed that their CARB 430 data was always in agreement with the FT-IR results when the exhaust gas had less that 60 ppm of NO_2. Their data does not suggest that CARB 430 data should rejected on the basis of NO_2 interferences as long as the exhaust gas contains no more than 60 ppm NO_2 in the flue gas. The ICCR Source Groups may in fact be able to supply evidence that the exhaust gas from their sources do not exceed 60 ppm NO_2 thereby dispelling concerns about the validity of the CARB 430 data from their emission sources, or certain groups of their emission sources. The data should, of course, still be subjected to the usual engineering and statistical reviews before it is used in the rule making process.

During our review of the Radian study, it became evident that the Radian used formaldehyde concentrations found by FTIR to determine the sampling volumes used for the CARB 430 measurements in order to ensure that sufficient excess of DNPH would be present to react with formaldehyde. Since at that time they had not yet learned of the NO_2 interference, they inadvertently used too large a sampling volume. A closer review of CARB 430 indicates that the method does not specify volume of stack gas to be sampled. It is therefore possible that some of the data present in the EPA data base collected by CARB 430 may indeed be valid, even if the NO_2 levels were high. However, in the absence of specific information

[2] A September 11, 1996 letter to Ms. Amanda Agnew of the EPA from Mr. James M. McCarthy of the GRI regarding Internal Combustion Engine Test Methods.

about NO_2 levels and sampling volumes for these tests, we believe that it is likely that these tests underestimate formaldehyde emissions from lean or clean burn engines.

B. Future Tests with DNPH Methods

The results of these field test show that formaldehyde emissions are likely to understated when determined by routine application of CARB 430 to lean or clean burn engines emitting high levels of NOx, in particular NO_2 . Operators of these type of sources should check their NO_2 emissions prior to doing any formaldehyde measurements to see if they have a potential problem. This can be accomplished using a portable NOx analyzer that provides NO and NO_2 data. The test contractor may than be able to adjust the sampling volume accordingly in order to avoid depletion of the DNPH by NO_2 .

Recent laboratory tested reported to GRI have succeeded in reproducing the step change decrease in formaldehyde concentrations when NO_2 concentration exceed 60 ppm. This was achieved by having the gas matrix containing formaldehyde and NO_2 more closely resemble that present in actual combustion gas emissions (i.e., including CH_4, CO, CO_2, NO, etc). This will permit the GRI to undertake laboratory experiments in the next few weeks that evaluate the Ashland and Celanese methods. Field studies evaluating these methods are planned in August-September 1997. The goal of these studies is to arrive at a cost effective method that will result in accurate measurements of formaldehyde emissions without necessarily having to employ the more expensive FTIR technique.

Our recommendation is that the DNPH procedures should not be rejected for future testing applications because of interferences that were observed with the lean and clean burn two-cycle internal combustion engines. Future testing is expected to result in an improved DNPH method which avoids interference present in emissions with high NO_2 levels. In addition, industry is also evaluating alternative procedures such as the Ashland method, a DNPH impregnated sorbent cartridge, and the Celanese method, an aqueous impingers techniques that measure total aldehydes.